FTD-ID(RS)T-1475-90

(2)

FOREIGN TECHNOLOGY DIVISION

ENERGY TRANSFORMATION PROPERTIES AND MECHANISMS IN TRANSVERSE FLOW DISCHARGED CO_2 LASERS

by

Wu Zhongxiang

Approved for public release;
Distribution unlimited.

HUMAN TRANSLATION

FTD-ID(RS)T-1475-90 10 December 1991

ENERGY TRANSFORMATION PROPERTIES AND MECHANISMS IN TRANSVERSE FLOW DISCHARGED CO_2 LASERS

By: Wu Zhongxiang

English pages: 7

Source: Zhongguo Jiguang, Vol. 16, Nr. 10, 1989, pp. 625-626

Country of origin: China
Translated by: SCITRAN
F33657-84-D-0165
Requester: FTD/TTTD/1Lt David W. Cason
Approved for public release; Distribution unlimited.

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WPAFB, OHIO.

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

TITLE: ENERGY TRANSFORMATION PROPERTIES AND MECHANISMS IN TRANSVERSE FLOW DISCHARGE CO_2 LASERS

AUTHOR: WU ZHONGXIANG

SUMMARY We simulated, calculated, and analyzed the effects on the various energy state transformation properties of dielectric media of such factors as dielectric media gas pressures, flow speeds, light cavity position, strength of radiation in the cavity, degree of output coupling, and other similar factors in transverse flow discharged CO_2 laser devices.

KEY TERMS Analog Calculations, Transverse Flow Discharge, CO_2 Laser

This article did concrete calculations of the corresponding energy transformation properties for the apparatus and the conditions in reference [1] (transverse flow, discharge, CO_2 laser device, dielectric medium constituent ratio of $CO_2:N_2:H = 5:17:78$, an initial temperature of 293K, a discharge current of 2A, E/N: 2.15×10^{-16} $V \cdot cm^2$, light cavity 160 cm^2 long (sic), height 1.8cm, as well as other parameters). In conjunction with this, from the patterns of the changes, it analyzed the related mechanisms.

1. Various Energy States Change Along With Changes in Gas Pressure P and Location x

With regard to the vibratory forms of energy above, E_N and E_3, one obtains $\ln E_N$ and $\ln E_3$-P curves at different locations x. When x is within an area of effective electrical excitation, $\ln E_N$ and $\ln E_3$ are increasing in a straight linear manner. When the current goes into the vicinity of the edge of an area of effective excitation, it gradually turns from going up to going down. Moreover, within that, the straight line portion of the slope of the increase or decrease stays basically unchanged in all cases, relative to x. $\ln E$, following along with the air pressure, presents this type of pattern of linear changes and is capable of being understood in practical terms as the effect of the electrical excitation pump and collision relaxation's all being in direct proportion to the dielectric media density, and the dielectric media density being in direct proportion to the gas pressure (due to the fact that, in the cavity, the changes in the average kinetic temperature are not great). In the vicinity of edges of areas of effective electrical excitation, lnE gradually turns from going up to going down, thus reflecting, at this time, the energy transformation mechanism's process of gradually turning from being basically involved with the electrical excitation pump to being primarily involved with collision relaxation.

The rule for the heat energy E_H and the descending vibratory energy state E_{12} at different positions x as they follow along with changes in the gas pressure P is that they are both straight linear ascending. Moreover, there is no relationship with whether or not x is inside an area of effective electrical excitation or outside it or whether it is inside the light cavity or outside it. The effects which the absolute value receives from the strength of radiation are also not large. This clearly shows that, under the relatively high gas pressures which are opted for in this article, the energy transfers from upper and lower vibratory energy states toward the basic state as well as from the vibration state above to the vibration state below and collision relaxation together dominate the effects. This is precisely the basic reason for the properties of relatively high pressure apparatuses being different from low pressure instruments.

2. x Positioned at the Exit Aperture of the Light Cavity. The Total Energy of the Upper Vibratory State $E_v(x_{Exit}) = E_3(x_{Exit}) + E_N(x_{Exit})$ Follows Changes in the Gas Pressure P and the Radiation Strength I.

It is possible to see $E_\upsilon(x_{Exit})$ as being the upper vibration state energy that still remains when the laser dielectric media flows through the light cavity and reaches the exit aperture. Under conditions in which the light strength I or the output degree of coupling C^- are the same in the light cavity, the $E_\upsilon(x_{Exit}) \sim P$ curves have $E_\upsilon(x_{Exit})$'s which all show the appearance of peaks in the vicinity of $P \cong 650$ Torr. When the degree of coupling is relatively large or the light strength is relatively weak, and, when, around $P \cong 650$ Torr, $E_\upsilon(x_{Exit})$ moving up or going down along with changes in P is, in all cases, monotonic, as well as when the degree of coupling is relatively small (for example, C=2.5%) or the light strength is relatively large (for example, $I=10^{12}$), after $P > 650$ Torr, the changes in $E_{\upsilon}(x_{Exit})$ following along with P first drop down and later, again, turn to going upward at a position with $P \cong 900$ Torr. At the vicinity of $P \cong 650$ Torr, $E_{\upsilon}(x_{Exit})$ shows the appearance of peaks. This is relatively close to the gas pressure at which the output power W_I, in reference [1], shows the appearance of peaks. Also, this corresponds relatively well with the turning point located at $x=x_{Exit}=0.6$cm in (1) previously. This clearly demonstrates that the the peak values on the curves for $E_{\upsilon}(x_{Exit})$ and W_I following changes in P are caused by the change from taking the electrical excitation pump as the main thing to taking collision relaxation as the most important thing.

When the light strength is relatively great, with $P \cong 900$ Torr, $E_{\upsilon}(x_{Exit})$'s drop following along with P again, turns into an upward climb. This is accompanied by the fact that, at approximately $P \cong 900$ Torr, the changes in $E_{\upsilon}(x_{Exit})$ following along with I, also, from the increases and reductions following along with I, turn into an increase. All of this clearly demonstrates that, at corresponding light strengths and degrees of coupling, the energy remaining in the upper vibratory state in the dielectric media, from an increase and reduction following along with the gas pressure, changes into an increase. In conjunction with this, it already reflects the effects on energy transformations of the strength or weakness of radiation in the cavity.

3. The Effects of the Strength of Radiation in the Cavity on Dielectric Media's Receiving Repeated Electrical Excitations.

When the strength of radiation in the cavity is very small ($I \cong 0$), at given gas pressures, the usable vibration energy supplied by electrical excitation is capable of being expressed as the upper vibratory energy $E_{\upsilon}(d)$ at the exit aperture of areas of effective electrical excitation d. The 626
efficiency of the conversion of the vibratory energy into light energy is capable of being expressed as:

$$\eta_{IU} = W_I/E_{\upsilon 0}(d), \qquad (1)$$

The maximum limiting value should be the quantum efficiency corresponding to the laser media ($\gtrsim$ 0.409). Taking the symbol η_{IU} for optimum output coupling conditions to be η_{IUm}, we make the $\eta_{IUm} \sim P$ curve, obtaining η_{IUm} values the great majority of which are obviously unreasonably larger than the quantum efficiency. This clearly shows that, when $I \neq O$, the total energy supplied to the upper vibration state of the laser dielectric media by the electrical excitation pump is very much larger than when I = O. As a result of this, the dielectric media, in the process of flowing through the light cavity, have total energies which are actually acquired by upper vibration states and should also include that portion of the power which has already been turned into output. Besides this, under relatively high gas pressures, E_U is not greatly related to the drop produced by collision relaxation and the strength of radiation. Because of this, during the output process, the total energy which is unceasingly replenished by electrical excitation to the upper vibration state is:

$$W_{UI} = W_I/0.409 + E_{UI}(x_{Exit} - E_{U0}(x_{Exit}) \qquad (2)$$

In this equation, $E_{UI}(x_{Exit})$ and $E_{UO}(x_{Exit})$ are, respectively, the upper vibration state energies remaining in the dielectric media at the exit aperture of the light cavity when the light strength in the cavity is I and O. This equation reflects, in the output process, that reexcitation of energy in the cavity, besides being related to output power and quantum efficiency, is also related to the difference in values between upper vibration energies which remain at the light cavity exit aperture when the light strength is I and O. Because of this, under the effects of strong radiation, the total effective vibratory energy W_{UI}^{+}, which is supplied by electrical excitation, and the efficiency of its transformation into light energy η_{IU}^{+}, are capable of being represented respectively as:

$$W_{UI}^{+} = W_{UI} + E_{U0}(d), \quad \eta_{IU}^{+} = \frac{W_I}{W_{UI}^{+}} \qquad (3)$$

The corresponding results are already sketched out in the various Fig.'s of reference [1]. In it, η_{IU}^{+}, under all conditions, is reasonably smaller than quantum efficiency.

As far as the results of calculations are concerned, the $(E_{UO}(x_{Exit}) - E_{UI}(x_{Exit})) \sim P$ curves, under different conditions of degree of coupling, all show the occurence of peak values in the vicinity of $P \cong 650$ Torr. Moreover, before and after them, all curves monotonically rise or fall.

The secondary excitation energy W_{UI} under conditions with light strength I, degree of coupling C, and optimum degree of coupling C_m as well as the maximum secondary or subsequent excitation energy W_{UIm} have curves as they follow along with changes in gas pressure P such that they all show the appearance of peak values in the vicinity of $P \cong 900 \sim 1000$ Torr. The drop in $W_{UI} \sim P$ curves in the vicinity of $P \cong 900 \sim 1000$ Torr is capable of being understood as secondary 3xcitation energies being caused to reduce due to increases in the upper vibration state energies remaining in dielectric media. The gas pressures associated with W_{UI} curve peak values are basically in line with the gas pressures which correspond to the peak values of vibration energy light output efficiencies in reference [1]. These all clearly show that, in the cavity, reexcitation energy W_{UI} as well as its changes following along with gas pressure and radiation strength are yet another mechanism to influence instrument vibration energy efficiencies.

4. Effects Associated With Light Cavity Entry Aperture x_o

In light cavities with different degrees of coupling C, gas pressures P=780 Torr, 200 Torr, etc., and widths ($\cong$0.5cm), W_{UI}, in all cases, shows the appearance of peak values at given positions x on $E_U(x_{Exit}) \sim x_o$ curves (P=780 Torr; the peak values are at $x_o = 0.1 \sim 0.2$ cm. P = 200 Torr; the peak values are at $x_o = 0.5 \sim 0.7$cm). This is capable of being understood as a condition where, within the effective electrical excitation area, the internal cavity electrical excitation pump is strengthened along with an increase in x_o. Secondary excitation in the process of radiation output is also increased. However, the increase in x_o also causes the length that the light cavity exit aperture extends beyond the area of effective electric excitation to increase. Inside the cavity, at the same time, the dielectric media received by the electrical excitation pump is reduced. This also causes, in the output process, a reduction in secondary excitation. These two factors follow along with increases in x_o and reciprocally grow and decline, causing $W_{UI} \sim x_o$ curves to show the appearance of peak values. $E_U(x_{Exit}) \sim x_o$ curves descend monotonically, reflecting, in the dielectric media, the pattern of remaining upper vibration state energy varying along with changes in the location of the light cavity.

With different light strengths I and gas pressures P = 780 Torr and 200 Torr, E_H and $E_{12} \sim x_o$ curves, in all cases, present the form of a broken line. The break points all correspond to the center of the light cavity (780 Torr and 200 Torr) or light cavity exit apertures (780 Torr) placed at the location of the effective electrical excitation area's exit aperture. This clearly demonstrates that, in the cavity, the overall effects of electrical excitation pumps and collision relaxation cause an increase in E_H and E_{12}. Moreover, following along with an increase in the length of the light cavity's shifting outward the effective electrical excitation area, there is also a corresponding reduction.

5. Effects of Flow Speed U

Adopt x_o = 0.1cm, air pressure P = 780 Torr and 200 Torr, and make W_{UI} and $E_U(x_{Exit}) \sim U$ curves. The results clearly show that, following along with increases in U, W_{UI}, in all cases, goes down monotonically. This can be understood as being a shortening of the retention time in the area of effective electrical excitation of the dielectric media. Because of this, in the dielectric media, the residual upper vibration state energy E_U increases. However, the probabilities of both receiving a radiation transition and of secondary excitation are reduced, that is, W_{UI} is reduced.

As far as E_H and $E_{12} \sim V$ curves under the same conditions are concerned, they all are straight lines following V upward. This clearly shows that the energy shifts from the laser energy state and from the upper and lower energy states to the basic state increase linearly along with increases in the dielectric media flow speed V.

REFERENCES

1. Wu Zhongxiang, et.al.; Chinese Lasers, 15(7), 431(1988)

(Draft received on June 6, 1987. Revised draft received on July 13, 1988.)

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION	MICROFICHE
B085 DIA/RTS-2FI	1
C509 BALLOC509 BALLISTIC RES LAB	1
C510 R&T LABS/AVEADCOM	1
C513 ARRADCOM	1
C535 AVRADCOM/TSARCOM	1
C539 TRASANA	1
Q592 FSTC	4
Q619 MSIC REDSTONE	1
Q008 NTIC	1
Q043 AFMIC-IS	1
E051 HQ USAF/INET	1
E404 AEDC/DOF	1
E408 AFWL	1
E410 ASDTC/IN	1
E411 ASD/FTD/TTIA	1
E429 SD/IND	1
P005 DOE/ISA/DDI	1
P050 CIA/OCR/ADD/SD	2
1051 AFIT/LDE	1
CCV	1
PO90 NSA/CDB	1
2206 FSL	1

Microfiche Nbr: FTD91C000748
FTD-ID(RS)T-1475-90